Carlia ailanpalai (Reptilia: Scincidae): An Invasive Species of Lizard in the Federated States of Micronesia[1]

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Abstract: Distribution of the introduced scincid lizard *Carlia ailanpalai* Zug in the Federated States of Micronesia (FSM) is reviewed. It is common in open grassy areas but seldom occurs in mature forest. Preliminary surveys indicate that it is well established in Yap, though less frequently encountered at increasing distance from Colonia, the main settlement, and it is unrecorded in the extreme northern and southern parts of Yap. It is the most common species of lizard in open, grassy, ruderal habitats throughout Weno Island, Chuuk, being nearly the only species encountered in the commercial district, but it is unknown elsewhere in Chuuk State. The only record for Kosrae is a single specimen collected in 1988 (first record for the FSM), but there is no evidence of an established population. There are no records for Pohnpei State. Guam is likely the primary source for the Yap and Chuuk populations (and Kosrae specimen), but the time of initial introduction is unknown. *Carlia ailanpalai* appears to have spread rapidly, at least on Weno, Chuuk, where it has become the predominant lizard in open habitats islandwide, possibly since the late 1960s. How *C. ailanpalai* interacts with other species in the FSM requires further study, but preliminary surveys of distribution and relative abundance suggest that it has a negative impact on populations of *Emoia jakati* and, to a lesser extent, on other *Emoia* species as well. Populations of *C. ailanpalai* in the FSM meet the criteria for invasive species status as it is defined by numerous U.S. government agencies and international conservation groups.

In his revision of skinks of the *Carlia fusca* group, Zug (2004) recognized 14 species. *Carlia ailanpalai*, one of six species that Zug (2004) described as new, and which was previously recorded under the name *C. fusca*, is known from the Admiralty Islands (off the northern coast of New Guinea) and extralimitally in the Mariana Islands (on Guam, Saipan, and Tinian) and on Yap and Kosrae in the Federated States of Micronesia (FSM). *Carlia ailanpalai* (Figure 1) probably was introduced to the Marianas sometime between the end of World War II and the early 1960s (Wiles et al. 1989). It was first collected on Saipan in 1964 (Dryden and Taylor 1969), on Guam in 1968 (McCoid 1993), and on Tinian in 1989 (Wiles et al. 1989) and has since become the most abundant skink on those islands (Wiles et al. 1989, Wiles and Guerrero 1996, McCoid 1999). It was introduced to Cocos Island (0.38 km^2), about 2.0 km off the coast of Guam, possibly as recently as the late 1980s (McCoid 1996). It was recorded at only two sites on Cocos in early 1989 but was abundant in all areas of the island by early 1991, thus indicating an ability to spread rapidly (McCoid 1996).

Carlia ailanpalai is an aggressor and predator in encounters with *Emoia caeruleocauda* on Guam (Wiles et al. 1989, McCoid 1995), and it is considered a possible causal factor in the decline in native scincid lizards in the Marianas (Case and Bolger 1991, Rodda et al. 1991, Rodda and Fritts 1992, McCoid 1993, 1995). Quantitative studies of interaction between

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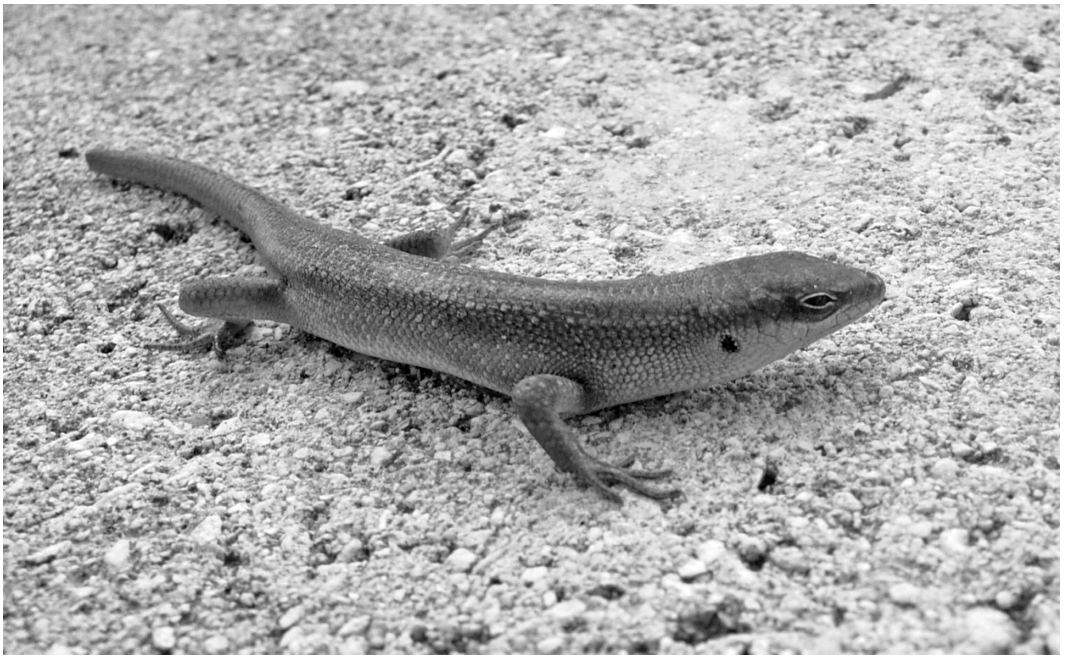

FIGURE 1. *Carlia ailanpalai* photographed on Yap; the four toes on the forefoot readily distinguish this species from other somewhat similarly colored species of skinks in the FSM, all of which have five toes.

C. ailanpalai and other skink species are lacking, but a review of museum specimen records for Guam for the years 1945–1990 shows a marked decline in the number of *Emoia caeruleocauda* with an equally marked increase in the number of *C. ailanpalai* over the same period (Rodda and Fritts 1992). Furthermore, *C. ailanpalai* is a substantial part of the diet of the brown tree snake on Guam and helps sustain the large population of snakes on the island (Rodda and Fritts 1992, Fritts and Rodda 1998, Rodda et al. 1999).

The Global Invasive Species Database (2005) did not include any species of the genus *Carlia* in its list of alien invasives, but the Guam Division of Aquatic and Wildlife Resources (GDAWR) (2005) and the Guam Invasive Species Advisory Committee (2005) recorded *C. ailanpalai* as an invasive species on Guam, and Pitt et al. (2005:116) considered it "invasive" in both Guam and the Northern Mariana Islands.

Little is known of the distribution and relative abundance of *C. ailanpalai* in the FSM; four specimens collected on Yap and one from Kosrae are the only previous records. This study was undertaken to shed additional light on the status of this species within the FSM, the initial impetus coming from my observations of this species in abundance in Chuuk, where it had not been previously recorded.

Study Area

The FSM extends approximately 2,500 km across the west-central Pacific Ocean from Yap State eastward to Chuuk (formerly Truk), Pohnpei, and Kosrae States and it makes up the greater part of the Caroline Islands chain, which includes also the Republic of Belau (Palau) immediately to the west. Pohnpei (355 km^2, 791 m high) and Kosrae (109 km^2, 630 m high) are the largest islands and have the greatest habitat diversity, including the region's most intact rain forest and the only cloud forest; both also have extensive mangrove forest along their shores. Chuuk proper approaches atoll status and comprises 19 high, volcanic islands, the

largest being Tol (34.2 km^2, 443 m high), and numerous small, low-lying sand cays and coral islands all within a 2,130 km^2 lagoon enclosed by a reef and its associated coral islets. Tol is a composite of three closely juxtaposed islands (Toll, Patta, and Polle) separated by mangroves with dredged channels to facilitate passage; the Onei peninsula of northern Toll Island (sensu stricto) is often treated as a distinct geopolitical unit. Tropical forest covers most of the slopes of the larger Chuuk Lagoon islands but has been largely degraded during centuries of human occupation, especially during World War II; coconut (*Cocos nucifera*) forest predominates on the small, low islands. Weno (= Moen) Island, is the administrative center and port of entry. An international airport, a deepwater harbor, and the main commercial district are on the western shore. Small villages are scattered along the perimeter of the island except for a short span of about two roadless kilometers on the east side.

The name Yap usually refers to Yap proper, which consists of four closely juxtaposed high islands (Rumung, Maap, Gagil-Tamil, and Yap) all enclosed by a single fringing and barrier reef system and having a total land area of 98 km^2 (maximum elevation 178 m). The interior region is hilly, with patchy forest (mainly in the ravines) and savanna (mainly on the central plateau and hilltops). Much of the land in Yap has been modified by centuries of human occupation and managed as agroforest, where native vegetation is partially cleared for cultivation. Colonia, the administrative center and the largest settlement, is centrally located on the eastern shore of Yap Island. Both Yap and Chuuk States include numerous far-flung, low-lying (approximately 2–4 m high), coconut-forest-clad coral atolls, with most of the islands being less than 10 ha in area. Pohnpei State has eight such outlying atolls and Kosrae none. Fais is a small (2.8 km^2, 20 m high) limestone-platform island in Yap State about 220 km east of Yap proper. The original vegetation on Fais doubtless has been greatly altered as a result of several years of intensive phosphate mining during the latter part of the Japanese administration in the late 1930s and early 1940s. All of the islands of the FSM fall within the equatorial rain belt and are wet enough to support a mesophytic vegetation (Mueller-Dombois and Fosberg 1998), though many of the smaller atoll islands lacking a freshwater lens are more xerophytic.

MATERIALS AND METHODS

Field surveys were conducted during 31 December 2006–2 January 2007 (Weno Island, Chuuk), 27 June–5 July 2007 (Weno and nine other islands in Chuuk Lagoon), 7–11 September 2007 (Kosrae), 2–15 December 2007 (Pohnpei), and 16 December 2007–3 January 2008 (Yap proper and Fais Island). Field surveys were supplemented by museum specimen records, reports from the literature, and my unpublished observations spanning approximately 15 yr residence in the FSM. Searches consisted of timed walks of various durations and distances along trails, roadsides, grassy areas, and other open area habitats favored by this species on other islands where it occurs. Forest habitats were visited briefly on Yap and Chuuk but not on Pohnpei and Kosrae. Encounter rates were determined by counting all identified individuals observed during timed walks; they probably underestimate population density in areas where vegetation is more dense and where lizards glimpsed only briefly were unidentified and others likely undetected. Chi-square goodness-of-fit tests were applied to frequency data using Preacher's (2001) interactive calculation tool. The data were standardized to encounters per hour (or per 2 hr in some comparisons) to avoid having expected values less than five. The 53 specimens collected in Chuuk and 16 in Yap were deposited in the Bishop Museum, Honolulu; Museum of Comparative Zoology (Harvard University); the National Museum of Natural History (Smithsonian Institution); and The Natural History Museum, London.

RESULTS

Yap

The first and hitherto only records of *Carlia ailanpalai* from Yap are four specimens (USNM 560094–97) collected in Colonia, Yap

TABLE 1

Relative Abundance of *Carlia ailanpalai* in Grassy, Weedy Habitats in Yap at Different Distances from Colonia during December 2007 and January 2008

Distance from Colonia (km)	Search Effort (min)	Lizards Observed	Encounter Rate (Individuals/hr)
0–1.0	120 (16.2%)	10 (35.7%)	5.0
1.1–3.0	60 (8.1%)	6 (21.4%)	6.0
3.1–5.0	125 (16.9%)	8 (28.6%)	3.8
5.1–7.0	140 (18.9%)	4 (14.3%)	1.7
7.1–11.0	295 (39.9%)	0	0

Island, by Ron Crombie and Greg Pregill on 19 July 2000 and first reported by Zug (2004). I observed *C. ailanpalai* frequently in the Colonia area and less frequently outside Colonia during June–August 2005. Preliminary surveys I conducted later in December 2007 (Table 1) confirmed these earlier incidental observations. I saw none in the extreme northern and southern parts of Yap proper. The locality most distant from central Colonia where I observed *C. ailanpalai* was a grassy, weedy roadside at the western end of Taafnilth Village, 7.0 km to the southwest. The encounter rate within 3.0 km of central Colonia was significantly greater than that beyond 3.0 km (Table 1, $X^2 = 6.639$, df = 1, $P = .00998$). Outside the commercial district of Colonia, *C. ailanpalai* was most numerous on the grounds of the nearly conjoined (separated only by a narrow gravel road) campuses of Yap High School and the College of Micronesia, 3.0 km to the south. I saw none in forest habitats, and I did not encounter this species anywhere on Fais Island during 17–21 December 2007.

Chuuk

I observed *Carlia ailanpalai* in Chuuk first in the commercial district of Weno Island in June 2003, where it was well established, as indicated by the abundance of adults and young; several were collected but not saved. There are no earlier records for Chuuk State. I collected 26 at different sites throughout Weno during a return visit in December 2006 and January 2007, and another 27 during June and July 2007. It was most abundant in open, grassy, sparsely vegetated areas, including roadsides, vacant lots, and manicured lawns, and it was especially numerous along fences, stone and cement walls, and in refuse dumps. The highest encounter rate I recorded was 32 in 7 min (274.3/hr) in a vacant lot alongside the main road approximately 0.5 km south of the Weno post office. Encounter rates were greatest in the settled areas, but I recorded *C. ailanpalai* also in a roadless tract on the east side of the island. I observed it from sea level to the grassy summits of some of the highest hills. Approximately 20 were seen (four collected) in 2 hr in tall, dense grasses near the top of Mt. Witipon (270 m), one of the highest points on the island, but none was recorded in the small patch of remnant forest on the summit, where *Emoia caeruleocauda* and *E. boettgeri* were common, and it was uncommon or absent in mature forest elsewhere on the island.

Carlia ailanpalai occurs in the commercial district of Weno almost to the exclusion of other species of skinks. Outside the commercial district, it occurs in ruderal habitats with *Emoia caeruleocauda* and, to a lesser extent, with *E. boettgeri* and *E. jakati*. The *Emoia* species are much more numerous in forested areas, where *C. ailanpalai* is absent or scarce. I did not encounter *E. jakati* with *C. ailanpalai* during the timed surveys on Weno, but I saw it there occasionally at other times; conversely, it was regularly observed on other lagoon islands where *C. ailanpalai* was unrecorded.

Carlia ailanpalai is unknown in Chuuk State outside Weno; searches totaling 7.8 hr among nine other lagoon islands with a mini-

TABLE 2

Statistical Data for Surveys of *Carlia ailanpalai* on 10 Islands in Chuuk Lagoon during December 2006–July 2007

Island	Area (km^2)	Distance from Weno[a] (km)	Search Effort (min)	Encounter Rate (Individuals/hr)
Weno	18.68	0	187	63.2
Fono	0.32	2.3	45	0
Tonoas	8.64	3.5	40	0
Fefan	13.07	5.3	45	0
Param	1.48	7.9	30	0
Uman	4.65	11.2	60	0
Udot	4.87	12.3	35	0
Romanum	0.75	18.2	60	0
Fanapagnas	1.55	20.0	30	0
Tol[b]	33.76	23	125	0

[a] Measured from U.S. Navy Hydrographic Office Charts HO 6048 (scale 1:55,180) and HO 6049 (scale 1:55,600) (Secretary of the Navy, U.S. Navy Hydrographic Office [1944]).

[b] Including Patta Island (90 min), Polle Island (30 min), the Onei district of Tol proper (30 min), and Tol proper (75 min).

mum of 30 min on each island revealed none (Table 2). The searches focused on school grounds, churchyards, and footpaths in and around settlements, all being habitats where *C. ailanpalai* is abundant on Weno and elsewhere in Micronesia. In addition I did not observe it on Nama Island and the four atolls composing the Mortlock Islands southeast of Chuuk Lagoon (Buden 2007), nor on Houk Island (= Pulusuk Atoll) and Onoun Island (on Namonuito Atoll), west and northwest of Chuuk Lagoon, respectively (unpubl. data), all during surveys between 2002 and 2004. Neither was it among 367 individual sightings of nine species of reptiles recorded for 24 of the low-lying coralline reef and lagoon islets in August 1993 (Kepler 1994).

Pohnpei

Carlia ailanpalai is unknown from Pohnpei State. Only 2 hr were spent in search of *C. ailanpalai* on Pohnpei during this study, and only in the main town, Kolonia, and in open, grassy, weedy roadsides and landscapes. As well, I did not encounter *C. ailanpalai* during an islandwide herpetological survey in 1995 (Buden 2000*a*), nor incidentally at any other time during my nearly 15 yr (and continuing) residence on the island beginning in 1993. Nor did I encounter it during surveys of terrestrial vertebrates on seven of the eight outlying Pohnpei State atolls from 1993 to 1998: Mokil and Pingelap atolls (Buden 1995), Ant Atoll (Buden 1996*a*), Pakin Atoll (Buden 1996*b*), Kapingamarangi Atoll (Buden 1998), Oroluk Atoll (Buden 1999), Sapwuahfik Atoll (Buden 2000b).The most frequently encountered lizard during the search for *C. ailanpalai* on Pohnpei was *E. jakati* (63.5/hr), which is in marked contrast to the absence or near absence of this species in areas occupied by *C. ailanpalai* in Yap and Chuuk. On Pohnpei, it was not always possible to distinguish *E. caeruleocauda* from *E. impar* and *E. cyanura*, which were also encountered during the search for *C. ailanpalai*, but a combined count for the three species yielded an encounter rate of 31.9/hr.

Kosrae

One specimen (USNM 284572) collected by Tom Fritts at the edge of forest near mangrove swamp on 28 January 1988 is the only record of *Carlia ailanpalai* from Kosrae. None was included among the 29 specimens of seven species of lizards in the California Academy of Sciences collected by Robert N. Fisher in 1991, and Fisher (pers. comm.) did not recall seeing any there. I saw none during approximately 3 weeks on Kosrae, from 20 June to 6 July 2002, although most of that time was spent on insect surveys, with the herpetological observations being incidental. I revisited Kosrae during 7–11 September

TABLE 3

Encounter Rates (individuals per hour) of *Carlia ailanpalai* and Two Species of *Emoia* in Grassy, Weedy Habitats in Yap and Chuuk

	Yap		Chuuk	
Species	Colonia (2.0 hr)	Outer Districts[a] (3.3 hr)	Weno (2.2 hr)	Outer Islands[b] (2.2 hr)
Carlia ailanpalai	5.0	0	53.6	0
Emoia caeruleocauda	38.0	54.2	5.9	5.9
Emoia jakati	7.0	16.7	0	8.2

[a] Maap (30 min), Gagil-Tamil (80 min), southern Yap Island (90 min).
[b] Tonoas (40 min), Uman (60 min), Fono (30 min).

2007 specifically to search for *C. ailanpalai* and saw none during surveys covering a total of 47.6 km in 12.4 hr along roadsides and other ruderal habitats between the airport and Walung Village. The route passed through all the major settlements, excluding Walung, and it included a circuit of Lelu Island, which is connected to the main island by a causeway. Furthermore, I did not see any *C. ailanpalai* during untimed, incidental, and opportunistic searches of yards, vacant lots, and other seemingly suitable habitats throughout Kosrae.

DISCUSSION

Carlia ailanpalai is introduced and established in the Federated States of Micronesia in Yap and Chuuk. The time and source of the initial introduction are unknown. A specimen collected in Kosrae in 1988 is the first (albeit anomalous) record of this species in the FSM; there are no other records for Kosrae and no indication that it was ever established there. The Yap and Chuuk populations (and Kosrae specimen) may have been derived from Guam, either directly in each case or by secondary dispersal from an initial point of entry into the FSM. The colonists probably arrived via air or sea cargo. Kraus (2003:77) remarked that 45.6% of amphibian and reptile introductions among the islands of the Pacific Ocean have resulted from cargo shipping, and Fisher (in McCoid 1993 and pers. comm.) collected a live *C. ailanpalai* in the passenger compartment of a commercial aircraft outbound from Guam in 1991.

In Yap, *Carlia ailanpalai* is most abundant in the commercial district of Colonia, which is the main settlement, and it is frequently encountered there with *Emoia caeruleocauda* and *E. jakati*. The two *Emoia* species are relatively more numerous in the outer districts of Yap proper, where *C. ailanpalai* is less frequently encountered (Table 3): *E. caeruleocauda*, $X^2 = 2.846$, $df = 1$, $P = .092$; *E. jakati*, $X^2 = 3.970$, $df = 1$, $P = .046$. Both emoias appeared to be more abundant still along forest trails where no *C. ailanpalai* was encountered, although ground cover and deep shadows hindered sight identifications. Other species of lizards I observed sympatric with *C. ailanpalai* on Yap, but encountered less frequently, include *Emoia atrocostata*, *E. boettgeri*, *Lamprolepis smaragdina*, and the introduced *Anolis carolinensis*.

Carlia ailanpalai is more abundant and more widespread in Weno, Chuuk, than in Yap, which is suggestive of its having colonized Chuuk first. The paucity of herpetological surveys in those areas doubtless has contributed to the species being unrecorded until very recently: Yap in 2000 (Zug 2004) and Chuuk in 2003 (this study). *Carlia ailanpalai* appears to have been absent in Chuuk, or very scarce if present, at least as recently as the late 1960s. It is not among the 148 specimens of six species of skinks from Chuuk in the Museum of Comparative Zoology collected by Ross Kiester in July and

August 1968, 71 of which are from Moen (Weno) and from localities where *C. ailanpalai* is now the predominant lizard. It is very unlikely that Kiester would have omitted this species from his collection had he encountered it and equally unlikely that he would have overlooked it if it was well established on the island. Alternatively, it may have been present then but in very small numbers and more easily overlooked.

Given the abundance of *C. ailanpalai* on Weno, its apparent absence on the adjacent lagoon islands (Table 2) is striking and puzzling, especially in view of the considerable, almost daily, commuter traffic between islands affording numerous potential opportunities for herpetological stowaways. *Carlia ailanpalai* may well have been transported to some of the outer islands from time to time, but environmental resistance factors, such as predation, may have prevented its colonization and further spread among Chuuk Lagoon islands. *Carlia ailanpalai* is conspicuous in its preference for open habitats, and potential colonists may be especially vulnerable to predation by rats, cats, and free-ranging chickens, all of which are common in the settlements where *C. ailanpalai* is most likely to be initially transported.

The absence of *C. ailanpalai* from Pohnpei also is somewhat surprising given the frequency of air and sea traffic from Guam and interisland commerce and travel within the FSM. *Carlia ailanpalai* also appears to be effectively absent from Kosrae, the lone record from 1988 being an anomaly and possibly representing the fortuitous capture of a recently transported and escaped individual.

Although the Invasive Species Advisory Committee (2006:1) states "there continues to be uncertainty concerning the use and perceived meaning of the term [invasive species]," the definitions adopted by United States government agencies and independent conservation groups worldwide tend to focus on two criteria: (1) nonnative (= alien, foreign, introduced, nonindigenous, exotic) status and (2) the threat, or potential threat, to indigenous species and local biodiversity. *Carlia ailanpalai* in Yap and especially Weno, Chuuk, appears to meet the basic criteria for invasive species status. *Carlia ailanpalai* is almost certainly a recent introduction to the FSM, the first records being within the past 10 yr and, at least in the case of Weno, being absent or extremely rare during a survey collection made in the late 1960s. In addition, preliminary surveys indicate that it probably displaces other longer-established species (e.g., *E. jakati* and *E. caeruleocauda*). In view of the negative impact *C. ailanpalai* apparently has had on some native species in Guam and the Marianas directly (Pitt et al. 2005), along with it being an important food resource for the brown tree snake (Rodda et al. 1999) and potentially other introduced predators, it may be advisable for local quarantine inspectors to be made more aware of this species to help prevent its establishment in Pohnpei and Kosrae States and to prevent further spread among Chuuk State islands.

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